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Do small green roofs have the possibility to offer recreational and experiential benefits in a dense urban area? A case study in Helsinki, Finland

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1. Introduction

Urban areas cover less than 3% of the earth's surface (SEDAC, 2011), but house more than half (54%) of the world's population (United Nations, 2014). Furthermore, it has been projected that 66% of the population is urban by 2050 (United Nations, 2014), which means an increase in residential and other built areas. This sets pressures for preserving and enhancing good quality natural and semi-natural urban green (and blue) environment, including, e.g. forests, parks and seasides – the so-called green infrastructure (European Commission, 2013). Innovative solutions, such as integrating vegetation with buildings (on roofs and walls) are needed as part of the green infrastructure, where adequate and diverse green space in dense urban areas is the planning target (e.g. Jim, 2013; Haaland and van den Bosch, 2015).

Numerous studies show that natural-like environments, such as forests and water areas, are rich in recreational and experiential qualities (e.g. Hartig et al., 2003; Tomalak et al., 2011; Hauru et al., 2012; Takayama et al., 2014). Moreover, some studies suggest that also small public green spaces, such as pocket parks less than 5000 m^2, or even a few green elements, such as street trees or flowerbeds within dense urban areas, may offer recreational and experiential benefits (e.g. Nordh et al., 2009; Peschardt et al., 2012; Peschardt and Stigsdotter, 2013; Lindall and Hartig, 2015). The role of such small-scale green in contributing to human well-being may increase in the future as cities get more populated (e.g. Thwaites et al., 2005). Furthermore, urban green spaces located near homes and workplaces are important from social and sustainable perspective, as they are easy to access (Neuvonen et al., 2007; Coombes et al., 2010), and have the potential to offer everyday recreational experiences, e.g. aesthetic pleasure and restoration from attentional fatigue (e.g. Swanwick, 2009; Peschardt et al., 2012; Lottrup et al., 2013; Hauru, 2015). Even short exposure to nature is beneficial for human well-being (Tyrväinen et al., 2014), reaffirming the importance of easy access to green areas.

Green (i.e. vegetated) roofs are one way to offer green spaces where people live and work. In this paper, we consider green roofs as those purposefully constructed for having vegetation on them. Depending on the constructional solution, as well as the amount (number, size and scale) of green roofs, they can provide various ecological and technical benefits, such as managing stormwater (e.g. Nawaz et al., 2015;

Versini et al., 2015; Kuoppamäki et al., 2016), and abating noise (Van Renterghem et al., 2013). Green roofs contribute to preserving and enhancing urban biodiversity (Madre et al., 2014; Gabrych et al., 2016; Kyrö et al., 2017) that is also argued to have positive effects on the health and well-being of people (e.g. Hanski et al., 2012; Carrus et al., 2015;). Furthermore, green roofs comprise a potential for making urban landscapes more relaxing, interesting and aesthetically appealing, and may add to the collection of green spaces for diverse user groups (Mesimäki et al., 2017).

To fully realize the potential of green roofs, knowledge is required on their affordance for various recreational and experiential benefits. In line with White and Gatersleben (2011), we suggest that people's experiences and preferences should be studied on roofs, instead of just leaning on results gained in ground level green spaces. A few previous studies (e.g. White and Gatersleben, 2011; Fernandez-Cañero et al., 2013; Lee et al., 2014) suggest positive responses towards vegetated over non-vegetated roofs, especially towards roofs with lush flowering vegetation. There is also some evidence that flowering, taller and diverse vegetation is more restorative and aesthetically appealing than a monotonous one with low vegetation (White and Gatersleben, 2011; Jungels et al., 2013; Loder, 2014; Lee et al., 2015). However, a lush green roof is not always possible, due to technical (e.g. load capacity), ecological (e.g. extreme heat or wind), economic, architectural or other limitations. Small and sparsely vegetated roofs may sometimes be the only option to offer at least a pinch of green in a dense urban environment.

Many studies examining experiences and preferences of green roofs (White and Gatersleben, 2011; Fernandez-Cañero et al., 2013; Lee et al., 2014, 2015), as well as the majority of studies regarding other green spaces (e.g. Ulrich, 1979; Kaplan and Kaplan, 1989; Tyrväinen et al., 2003; Tveit et al., 2006; Blumentrath and Tveit, 2014), were based on visual evaluation of images. However, on-site studies allow for an exposure to the real-life environment (Scott and Canter, 1997; Özgüner and Kendle, 2006). Jungels et al. (2013) and Loder (2014) examined people's experiences of real roofs, arguing that access, scale and the distance from which one observes, influence the perception of a green roof. Moreover, Loder (2014) suggested that besides visual, other experiential aspects, such as multisensority, should be taken into account in green roof designs.

55 *1.1 Study objectives*

56

57 Our main research question was whether a small and sparsely vegetated green roof in a dense urban area has
58 potential for offering experiential benefits. More specifically, we explored the experiential quality of the
59 green roof, including restorative, aesthetic, and other types of multisensory experiences that are
60 multidimensional themselves, i.e. reflect different perceived qualities of the environment, as described below.

61 *Perceived restorativeness* is a well-known approach for studying experiential qualities of
62 environments. It refers to a feeling of psychological restoration that indicates recovery of the ability to direct
63 attention, which is important in the everyday urban life often loaded with demanding tasks and stress-
64 inducing stimuli (cf. e.g. Kaplan, 1995; Hartig et al., 1997). Restorativeness has been suggested to reflect
65 four perceived qualities of an environment: 1) fascination, including the wish to explore and the environment
66 being interesting; 2) compatibility with one's own needs and desires; 3) coherence, i.e. parts fitting together
67 and to a larger whole; and 4) being away, i.e. a feeling of getting away from the everyday worries and hassles
68 (e.g. Kaplan and Kaplan, 1989; Korpela and Hartig, 1996; Hartig et al., 1997).

69 Besides restorative, the experiences of natural environments and green spaces reflect many other
70 types of perceived qualities, such as unity, congruence and complexity (Kaplan and Kaplan, 1989; Tveit et
71 al., 2006; van Berkel and Verburg, 2014), cultural aspects (Hands and Brown, 2002), scale and mystery
72 (Kaplan, 1989; Tveit, 2006; Kirillova et al., 2014), diversity and species richness (Ode and Fry, 2002; Grahn
73 and Stigsdotter, 2010; Hauru et al., 2014; Kirillova et al., 2014), visual interestedness (cf. e.g. Hauru et al.,
74 2014; Pazhouhanfar and Kamal, 2014), nature and naturalness (Coeterier, 1996; Grahn and Stigsdotter,
75 2010), multisensority (e.g. colour and smell, Coeterier, 1996; sound, Kirillova et al., 2014), and beauty (cf.
76 Gobster et al., 2007; Hauru et al., 2014; Kirillova and Lehto, 2015).

77 Finally, a person may like and accept an environment independent of the above qualities (e.g. Ribe,
78 2013; Hauru et al., 2014). Therefore, we also studied the overall preference and acceptability of the observed
79 environment.

80

81

2. Material and Methods

2.1 Study site: small and sparsely vegetated green roof in a city centre

Our study green roof is located in Helsinki, Finland, a city with approximately 600 000 inhabitants and a population density of 2 785 inhabitants per km^2, at the time of the data gathering (2012) (OSF 2016). The roof (Fig. 1) is on top of the University of Helsinki Language Centre and surrounded by other buildings so that the vista from the roof contains only a skyline with roofs and walls of buildings. The roof is non-smoking, occasionally used by the personnel for short breaks. The total roof area is 130 m^2, with approximately 70 m^2 covered by vegetation. Most of the vegetated area of the roof consisted of mosses and a few Sedum species with a thin (3 cm) substrate. In addition, there were eight experimental plantings 2 - 3 m^2 each, with 6 - 8 cm substrate depth. Two of them were barren, with just a sparse scatter of seedlings, and the rest covered with meadow-grass vegetation. There was a paved path, and a patio with three flower pots, two chairs and a table (Fig. 1; Electronic Appendix A). A construction site nearby caused some noise.

Fig. 1

2.2 Data generation and the respondents

During the World Design Capital Helsinki year in 2012, visits to innovative university facilities were organized by the Public Relations Unit of the University of Helsinki, advertised via their customary channels. These events were open to all, but a registration was required to control the number of participants. Thus, the visitors were voluntary citizens, selected in order of registration. We conducted an on-roof survey during four similar events that included a visit to the study roof and a tour at the new University Library.

The visits to the roof and the surveys were conducted during four days: 5.9.2012 (two visits: 11 a.m. and 17.00 p.m.), 11.9.2012 (11.30 a.m.), 13.9.2012 (17.30 p.m.) and 15.10.2012 (16.30 p.m.). Weather was sunny or cloudy with mild/moderate wind (the mean hourly wind during the visits ranging between 2,1–5,9

m/s, with an average of 4,4 m/s; Finnish Meteorological Institute). The temperatures varied between 8 and 18°C (mean t/h during the visits; Finnish Meteorological Institute). The researchers gave a 15–20 min general introduction to green roofs in a seminar room with no view to the study roof prior to the visits. After this, visitors were taken to the green roof in groups of 30–46 people and given a questionnaire, with an explanation that it is for academic research and that they have a free choice to participate or not. The respondents were instructed to fill in the questionnaire individually, without discussing with anyone, and to return it after completion. Filling in the questionnaire took 10–15 minutes.

Altogether 178 people participated in the survey. However, as some of the respondents did not answer all questions, the number of respondents varied across the questions (from 150 to 176). 70% of the respondents who told their gender (n = 164) were female. The respondents represented a variety of fields of expertise, and age groups between 20 to over 70 years. Most (99%) of the respondents lived in an urban area. Age, living environment, and expertise of the respondents are presented in detail in the Electronic Appendix B.

2.3 Questionnaire

The questionnaire consisted of a section including the Perceived Restorativeness Scale, PRS (Hartig et al., 1996, 1997), and it was complemented with statements, adjectives and open questions targeted at revealing other perceived qualities on the roof (see Electronic Appendix C).

The PRS included 16 statements that were originally constructed to measure four restorative qualities of an environment (Hartig et al., 1996; Electronic Appendix C). The respondents rated their (dis)agreement with each statement on a scale from 1 (*not at all*) to 7 (*completely*) in agreement with the statement.

We supplemented the PRS with statements we had used earlier (2012) in a study that examined aesthetic qualities of urban forests (n=287, Hauru et al. 2014). These statements, some of them modified to be applicable on the roof, measured multisensority and perception of beauty (statements 17 - 19), mystery (statement 20), understanding of the environment (statement 21), visual interestedness (statement 22), as well as diversity and nature (23 - 25). To explore the acceptability of the green roof in the urban context, we asked

136 the respondents how modern they thought the place is (statement 26), and how well the roof fits into the city
137 (statement 29). Moreover, we inquired the general acceptability (preference) of the roof (statements 27 - 28).
138 We complemented the statements by 17 adjectives. This method was inspired by previous studies that
139 used adjectives as contrasting pairs (e.g. beautiful vs. ugly) or as ranking lists, to characterize and evaluate
140 different kinds of environments (cf. e.g. Stewart, 2007; Akalin et al., 2009; Jeon et al., 2012; see also
141 Lindemann-Matthies and Marty, 2013). We used a list of single adjectives that were evaluated on the same
142 scale as the statements above (i.e. from 1 to 7). This list of adjectives was piloted in 2012 in urban forests
143 (n=287, unpublished data).
144 At the end of the questionnaire, we included six open questions which allowed respondents to provide
145 free-form answers that could offer in-depth understanding and to reveal perceived qualities not gained
146 through the closed questions. The questions concerned aesthetically appealing and disturbing things on the
147 roof, as well as feelings evoked by the place. As we assumed that first observations in the environment may
148 affect the overall experience on the roof (see e.g. Hietanen and Korpela, 2004 and refs. therein for affective
149 priming; O'Connor et al., 2016 for first impressions), we asked what things first caught the attention of the
150 respondents. Similarly, as the acoustic environment is suggested to influence the overall comfort in urban
151 open spaces (e.g. Yang and Kang, 2005), and as smell is argued to have a role in urban environmental
152 experience, perception, and place identity (cf. Henshaw, 2014), we also asked about the sounds and scents.
153 Finally, by asking about feelings we targeted the emotional dimension of experiences (cf. e.g. Carroll, 1993;
154 Brady, 2003).
155 The questionnaire with altogether 45 items (statements or adjectives), and six open questions in
156 Finnish, was translated into English for publication.
157
158 *2.4 Analyses*
159
160 To be able to compare the restorative capacity of the roof to literature, we first ran a factor analysis with the
161 16 PRS statements only. Studies have shown that the 16 statements tend to load on two instead of four
162 factors in factor analyses, reflecting general restorativeness (combining statements measuring fascination,

being away and compatibility) and coherence (e.g. Hartig et al., 1996, 1997; Korpela and Hartig, 1996; Hauru et al., 2012).-Therefore, we conducted a confirmatory factor analysis (Principal Axis Factoring) to test whether the 16 PRS statements form the two factors (i.e. the factor number was fixed to two). We used promax-rotation that allows correlation between factors and tested the internal consistency of the factors with Cronbach's alpha coefficients. Finally, we calculated the mean scores for the factors. Similar to previous studies (e.g. Hartig et al., 1996; Korpela and Hartig, 1996; Hauru et al., 2012), we reversed the scales of the negatively tuned statements (3, 11, 12 and 13, see Electronic Appendix C) to make them parallel to the rest of the statements.

While we had a list of the tentative perceived qualities, as presented above in section 1.1, we also hypothesized that there could be experiential qualities yet unidentified. Therefore, we ran an exploratory factor analysis with the whole dataset, without a priori fixing the factor number. We used similar methods as described in the previous paragraph, also reversing the scales of the negatively associated adjectives (ugly, restless, everyday, boring, confined, scary). The 16 statements of the PRS, the 13 other statements and the 17 adjectives gave an 11-factor solution (retaining factors with eigenvalue ≥ 1). Three more solutions with 8, 9 and 10 factors were explored (cf. Preacher et al., 2013), but they included nonsensical factors with no distinctively high factor loadings. The factor composition was interpreted by the three researchers of this study independently and then discussed to reach a mutual understanding of the meanings of the emerging factors.

We conducted a two-phase analysis of the free-form answers. First, we categorized the answers to each question by using a double-blind method where two researchers classified the answers independent of each other, and the final composition of categories was determined in mutual discussions. We identified and counted mentions, i.e. meaningful words and phrases in the answers. As the closed questions preceding open ones may direct the respondent to use the same kinds of expressions in the open responses, we closely scrutinized all expressions in the free-form answers, and evaluated whether they further explained the findings, or opened new avenues.

3. Results

The respondents scored high for perceived restorativeness on the roof. The results also revealed multiple perceived qualities that reflected visual as well as other sensory experiences, beauty, suitability of the place for oneself and the urban context, nature, desire to explore and interestedness, positive excitement, break from everyday, and safety. The free-form answers supported the results of the closed questions, but also revealed other experiential dimensions, such as feeling of spaciousness and freedom, strong positive feelings, and issues concerning design.

3.1 Perceived restorativeness was high

The two-factor solution for the 16 PRS statements reflected General Perceived Restorativeness (GenPR) and Coherence (Table 1). Cronbach's alpha values were similar to previous studies: for GenPR it was 0.93, indicating a good internal consistency, and for coherence 0.68 indicating a moderate or questionable internal consistency (e.g. Korpela and Hartig, 1996). Correlation between these two factors was not too high (0.41), thus we dealt with them as individual components. The mean rating of statements loading on GenPR was 5.07 (min = 2.75, max = 7, s.d. = 0.81) and on Coherence 5.59 (min = 2.75, max = 7.00, s.d. = 0.86).

Table 1

3.2 Exploratory factor analysis resulted in 11 perceived qualities

The factor analysis of all the 29 statements and 17 adjectives resulted in 11 factors (factors A - K, Table 2), with the cumulative percentage of variance explained being 58. Below, we describe the content of each factor based on the highest loadings of statements on each factor (Table 2).

Table 2

Factor A reflects Visual Interestedness towards the place and the many aspects of aesthetic experience (e.g. diversity, excitement, beauty and harmony). Factor B gathers together statements that reflect Compatibility between the Place and Oneself, including feeling of oneness, belonging, and understanding the place as well as escape from the everyday. Factor C reflects Serene Beauty, with high loadings of the reversed statements for, e.g. chaos and distraction. Also, the reverse of the adjective *Ugly* gets its highest, and *Harmonious* gets its second highest loading on factor C.

Statements concerning General Likeability, as well as modernity and acceptability of the place as part of the city load strongly on factor D, and also the reverse of *Boring* gets its highest loading here. Factor E gathers high loadings of statements reflecting Freshness and Pleasant Soundscape, combined with perceiving the place as mysterious. Factor F reflects Tempting Nature, as all the adjectives and statements describing living verdant nature get their highest loadings here, together with the adjective *Tempting*. Also, statements and adjectives mirroring fascination, likeability and multisensority (visual interest, soundscape, freshness) get relatively high loadings on this factor.

Exploration manifests itself on factor G, through statements reflecting desire for exploring the place and fascination. Factor H represents the place being Safe and Comfortable (and not scary, restless or confusing), as well as green and alive. Statements reflecting suitability to one's personality get their highest loadings on factor I that also reflects the place being Interesting in Many Ways: there are many ways to enjoy the place, and many interesting things to observe. The place being Exciting and Attracting distinguish in factor J and finally, factor K stands for Break from Everyday Routines, with the place being mysterious getting its second highest loading.

Pairwise correlations between the 11 factors varied from very low (0.07 between H Safe and Comfortable. and K Break from Everyday Routines) to moderate (0.61 between K and J Exciting and Attracting see Table 2). Communalities of the statements and adjectives in the 11-factor solution were sufficiently high in general: only statements *It is a confusing place*, *This looks like a place where many insects and invertebrates live*, and *This place is modern*, had communalities lower than 0.30.

An evaluation of the overall scores of individual statements and adjectives revealed a positive environmental experience. The overall mean across all score values for the positive statements or adjectives was 5.1 (*fairly much*). The ultimately highest scores reflected the acceptability of the place: *It is good places like this exist*, *I like this place*, *Places like this fit into the city*, and the adjective *Safe*, were all represented by value 7 as the upper quartile and with a mean of 5.7 - 6.6. *Places like this fit in into the city* also received the lowest standard deviation of the scores (0.6) among all statements and adjectives, i.e. there was a high consensus that places like the roof are suitable for cities.

All the lowest scores (with the scores 1 or 2 representing the first quartile) were received by the negative expressions, with the mean per statement/adjective ranging from 1.6 to 3.2. Furthermore, the statements *The soundscape is pleasant here* and *This looks like a place where many insects and invertebrates live* got average score values less than 4 (3.9 and 3.7. respectively).

3.3 Open questions revealed a rich set of perceptions and experiences

In this section, we present themes identified in the free-form answers (for the detailed classification of answers, see Electronic Appendix D).

The first thing that most of the respondents (53% out of 178) paid attention to when entering the roof, was some form of living nature. Only a few (4%) reported negatively tuned impressions, e.g. the small size of the roof. Mosses were the most frequently mentioned single nature element (15% of the 336 mentions to this question, Fig. S10, Electronic Appendix D). Many other elements were also paid attention to when entering the roof, such as concrete slabs and furniture on the roof (17% of the mentions). Features related to the roof design were quite frequent (13% of the mentions, e.g. forms, shapes and unity of elements on the roof), as were colours and verdancy (13% of the mentions): ‘Green moss – red sand – grey stones – beautiful’. The environment on and around the roof also received various characterisations, such as ‘A peaceful place high up’, ‘It feels as if I stepped in the middle of a forest’, ‘Roofs, sky, spaciousness, just as if I was in Middle-Europe!’.

As aesthetically pleasing features on the roof, 60% of the 178 respondents mentioned, again, some form of living nature. Also here, mosses were the most frequently mentioned single nature element (12% of the 338 mentions to this question, Fig. S11, Electronic Appendix D). Many respondents mentioned colours and their combinations, as well as verdancy (18% of the mentions): 'Colourfulness of different moss species.' Design aspects, including rhythm, symmetry, scale, horizontal and vertical dimensions, and different textures were mentioned relatively often (14% of the mentions): 'Small scale on the roof of a big building.' Furthermore, single (non-living) elements on the roof and features of the built environment around the roof were considered as aesthetically pleasing ('surprising spaces around the roof', 'layers of time in architecture'). Some reported closeness of sky and horizon, and characterized the roof space as aesthetically pleasing, e.g. 'beautiful courtyard'.

The most frequent disturbing thing on the roof was noise, mentioned by one third of the 178 respondents (34% of the 175 mentions to this question, Fig. S12, Electronic Appendix D), mainly due to an air conditioner on the roof (e.g. hum, creak): 'Soundscape is somewhat industrial.' Sounds of traffic were reported as disturbing only by two respondents. Features related to the built environment and landscape outside the roof were also mentioned as disturbing (14% of the mentions, e.g. walls, a construction site nearby). Some respondents mentioned non-natural elements on the roof (e.g. concrete slabs) as well as lack of vegetation, and used characterizations such as small, cramped or restless, messy, and too formal.

66% of the 178 respondents mentioned hearing the air conditioning nearby (40% of the 292 mentions to this question, Fig. S13, Electronic Appendix D). Other sounds mentioned were traffic (17% of the mentions), construction (16%), human (such as talking, walking or coughing, 16%). Sounds from the street or cityscape, e.g. 'hum of the city', and nature (e.g. birds, wind) were also noticed.

To the question of what the respondents smelled, 12% of the respondents left the space empty, i.e. did not answer anything. Some respondents marked ' – ' (N=26, not counted into the mentions) that may indicate smelling nothing, or 'no answer'. The number of mentions to this question was 153, i.e. lower than to the other open questions. Most mentions here included fresh and clean air or wind (27% of the mentions, Fig. S14 Electronic Appendix D). 21% reported to smell nothing or almost nothing. Scents such as food (20% of

294 the mentions) and nature (16%, e.g. forest, tuft, moist, autumn), as well as scents from the cityscape (10%)
295 were mentioned. ‘Pleasant scent of sunshine, wind and city centre.’

296 The biggest category of feelings reflected positive emotions such as pleasure, joy, sympathy,
297 admiration and love, mentioned by 37% of the 178 respondents (26% of the total of 249 mentions to this
298 question, Fig. S15, Electronic Appendix D) – ‘warm and joyful feelings’, while 11% of the respondents (8%
299 of the mentions) reported negatively tuned feelings (e.g. boring, disappointment) or related to confusion:
300 ‘Perhaps I waited for something more, where is the real nature?’. Peaceful and relaxed feelings, e.g. ‘a
301 calming city corner’, ‘calming greenness!’, composed 22% of the mentions. One set of feelings (19% of the
302 mentions) reflected excitement, inspiration and expectancy for the idea of having green roofs: ‘Hope for this
303 country and the world.’ Moreover, some respondents expressed a desire to stay longer, come back, or do
304 something on the roof (e.g. lie in a hammock, look at the sky, follow plants over time, ‘desire to stay and
305 enjoy the space and the moment’). The feelings related also to freedom and familiarity (‘atmosphere of the
306 childhood yard’) as well as character of the place, e.g. ‘as in the old towns of Central-Europe’. A couple of
307 respondents expressed envy for those who have the possibility to use these kinds of places.

308 Finally, analysing all the free-form answers together revealed themes that were not apparent from
309 analysing the answers to each question separately. Expressions of spaciousness and openness, height and
310 light with feelings of liberty, as well as freedom and being close to sky, were recognized in the answers to
311 questions 1, 2, 4, 5 and 6. These, together with sensing freshness and clean air (responses to question 5),
312 encapsulated in the mention ‘freedom to breathe’, and longing for vistas over the city (responses to question
313 3) reflect a liberating multisensory experience (see Electronic Appendix D).

314 The ground materials, the gravel, and the crushed brick were mentioned several times in questions 1
315 and 2, while these were not at all mentioned as disturbing things: ‘different substrates side by side’, ‘beautiful
316 substrate’. Furthermore, other answers may refer to substrates indirectly, e.g. ‘flowers, the division of space
317 into sections’, or ‘the whole, colours’ that were first paid attention to, or ‘moss, colours and composition’ that
318 were mentioned as aesthetically pleasing. Moreover, the surface of the roof received attention through
319 comments concerning the paths and the stepping stones on the roofs (positive) and the concrete slabs (also

negative, considered artificial). Wind was mentioned by 34 respondents across the dataset (altogether 40 times), and seven respondents considered it disturbing.

4. Discussion and design implications

This study showed that a small and sparsely vegetated green roof, located between buildings in an urban milieu, may provide various types of recreational and experiential benefits. Our findings are in line with previous studies conducted in small urban parks at the ground level, showing that even a small piece of green in the city can offer experiential and recreational benefits (e.g. Nordh et al., 2009; Nordh and Østby, 2013; Peschardt and Stigsdotter, 2013). Our results also support the ideas by Lee et al. (2014) that in urban spaces surrounded by high buildings, even low-growth grassy vegetation can be highly valued. Furthermore, as Thwaites et al. (2005) proposed, small, human-scale spaces may offer comfortable and restorative surroundings in urban environment.

Furthermore, our results showed that some features (e.g. the roof design and the surrounding sceneries) can be seen both as aesthetically pleasing and disturbing, depending on the respondent, thus reflecting the subjectivity of experiencing places and spaces (cf. Relph, 1976). Nevertheless, asking people's experiences is important, as experiential qualities of urban spaces cannot be assessed only by measuring physical features of environments (cf. e.g. Lothian, 1999).

In the following sections we sum up the factorial solutions as well as the qualitative results to generate an overview of the multiple experiential dimensions that a small green roof could provide.

4.1 Preliminary conditions: safety and greenness

This study showed that a small and relatively barren green roof in a city centre provides a diverse set of perceived qualities that manifest at different experiential levels (cf. e.g. Leder et al., 2004; Tveit et al., 2006). Some qualities clearly reflect the so-called preliminary conditions, such as safety and comfort, as well as the

roof being verdant (factor H in the exploratory factor analysis). Also van Herzele and Wiedemann (2003) suggested that properties such as safety may operate as preconditions for the use of an environment, and, once these conditions are fulfilled, qualities such as unity and naturalness start affecting the people's willingness to stay there. Our recommendation is that the starting point for green roof design should include guaranteeing the feelings of safety and comfort and offering a living green roof ecosystem.

4.2 Restorative potential of a small urban green roof

The level of perceived restorativeness on the study roof was quite high (mean GenPR 5.07 on a scale 1 - 7), even when compared to urban forests in Helsinki where the mean PR per forest site varied between 3.9 and 5.1, on a scale 1 - 7 (Hauru et al., 2012). To our knowledge, only a few studies have surveyed perceived restorativeness of green roofs. White and Gatersleben (2011) showed that perceived restorativeness was significantly higher for photos of buildings with integrated vegetation compared to those without. According to Lee et al. (2015), the restorative effect of a green roof occurred already after a 40-second viewing of a flowering roof. These two photo-based studies, even though they used a different version of PRS than we, are in line with our results that green roofs can provide restorative experiences.

Together with the relatively high perceived restorativeness, the many mentions concerning peaceful and relaxed feelings in the free-form answers, and the low scores of the adjective 'restless' indicate that the roof could provide a respite that the visitors enjoyed – a place to rest for a moment. Furthermore, the various mentions in the free-form answers concerning activities on the roof, e.g. to lie in a hammock, relax with a book, look at the sky, meditate, or observe plants over time, indicate the unhurried ways these kinds of spaces could be enjoyed: 'I could come here to calm down, I would like to stroke the moss.' This is in line with mental images (hopes, needs, wishes) of urbanites (studied by Mesimäki at al., 2017) that suggested that green roofs can offer relaxing spaces for 'everyday renewal', especially at work.

Although earlier research indicates that lush and flowering green roof vegetation would be more beneficial for restorative purposes than low-growth one (White and Gatersleben, 2011; Lee et al., 2014; Loder, 2014), ascetic greening remains a good option when load capacity or other circumstances limit the

choices. The relatively short period of flowering nature in the northern climate underlines the need for 'background green planting' that still may offer restorative experiences (Hoyle et al., 2017). Based on the richness of mentions in our data concerning the ground materials and composition, a hypothesis could be put forth that one could also design with substrate colour and materials as well as topography to offer richer experiential qualities than can be achieved with uniform flat designs. Nordh et al. (2009) argued that the possibility for restoration is in relation to the design and the components of small (< 3000 m^2) pocket parks. Thus, there is an urgent need for research on the particular design aspects in order to achieve this (Velarde et al., 2010).

The multiple reactions revealed by the free-form answers to the built environment including modern and historical styles (see Electronic Appendix A), indicate the importance of the whole scenery in how the respondents experienced the place. For example, perceived restoration is not only specific to natural places but can be achieved in urban places too (Korpela et al., 2010), and may depend on the variability of the scene (Tenngart Ivarsson and Hagerhall, 2008), as well as types of buildings and architectural styles (cf. Korpela, 2013, Stigsdotter et al., 2017).

4.3 Two dimensions of escaping everyday

Experiencing compatibility of oneself with the place and escaping the everyday actualized in the same factor (B), and also through the free-form answers, such as 'own place in the middle of urban scenery', thus reflecting a possibility to withdraw from everyday hassles to a place suitable for oneself. This comes close to perceived restorativeness, and indeed, the statements getting the highest loadings on this factor were originally statements of the PRS (cf. Hartig et al., 1996). At the same time, the statement reflecting a break from the everyday routines was the strongest determinant of factor K that had quite a low correlation with factor B. This suggests that these two factors might reflect separate dimensions of escaping the everyday.

While factor K associated the break from day-to-day routines with beauty, temptation, fascination, and mystery, factor B associated the escape experience with the suitability of the place to oneself. This is in

line with the classical Attention Restoration Theory presented by S. Kaplan (1995) that mention fascination and compatibility among the four components that characterize an environment's restorative potential.

Interestingly, factor B comes close to the concept of place identity as presented by Bryce et al. (2016), who used statements such as 'I feel a sense of belonging in these sites'. The nostalgic feelings and memories described by some respondents (free-form answers), further indicate a strong connection between the observer and the place.

4.4 Exploration and mystery

In our factor solution, exploration was reflected through practical statements of wanting to explore and look around, together with fascination. In previous studies, exploration has been linked to complexity and mystery, for example Kaplan and Kaplan's (1989) preference matrix model and studies based on it (see Stamps, 2004 for a meta-analysis). However, in our study this practical wish to explore did not clearly relate to complexity-diversity nor mystery. Our hypothesis is that on this particular roof, small in size, exploration was not connected to prospect, i.e. spaces one wants to go to, but rather to investigating and observing the space that is already within one's experiential sphere. The open questions gave support to this, with answers that stated a wish to explore the environment closer: 'I would like to look at the mosses at the eye level.', 'It would be interesting to visit here, for example, in the rain. As a friend of bugs, it would be fun to see them as well.' However, despite this quite practical exploration-dimension, paths were mentioned several times as aesthetically pleasing elements in the free-form answers, e.g. 'A permitted passageway has been created to the railings.', suggesting that also the prospect kind of exploration can be achieved to some degree even in a small space if design is given some thought about that dimension.

As for mystery, Stamps (2004), in his meta-analysis of the Kaplans' mystery-complexity-legibility-coherence model (1989), discussed the varying results concerning mystery, defined as 'How much does a scene promise more if you could walk deeper into it?'. Based on our findings that the statement concerning the place being mysterious had its three highest and equal loadings on factors reflecting freshness/pleasant soundscape, nature, and break from daily routines, we suggest that the conceptualization of mystery might be

too weak (cf. e.g. Hofmann, 2012). It would be important to reconceptualise and operationalize mystery and empirically reassess its role among the perceived environmental qualities. Mystery might best be explored as multisensory perceptions experienced on-site and not, e.g. when looking at a picture of a landscape (cf. Kaplan and Kaplan, 1989).

4.5 Positive feelings and hope for the future

The free-form answers revealed experiences not traditionally recognized in the literature concerning urban green spaces, such as perceived on-site happiness, joy, love, sympathy, admiration, and pleasure. The manifold of positive feelings may indicate a favourable a priori attitude as well as the on-site experiential quality. These expressions were abundant, and much more so than expressions of disappointment (some of which also occurred). Also, Mesimäki et al. (2017) found positive expressions (e.g. happy, smile, joy) in the stories for imaginary green roofs as a distinct theme. Thus, it would be fruitful to further investigate the role of various positive feelings as part of the effects of urban green spaces for well-being: though scales exist for measuring perceived happiness, it is mostly related to people's personalities and lives in general, and not to experiential qualities provided by urban greenspace.

Moreover, the free-form answers reflected expectancy, enthusiasm, curiosity, surprise and admiration. For example, hope for the future was expressed as a feeling evoked by the roof. It may be that for some respondents, the place represented progress and modern urban design, a theme found also in the mental images of urbanites for green roofs (Mesimäki et al., 2017), and described by Loder (2014) as 'surprise and fascination' of vegetation existing in a very constructed urban space, and nature on a roof as a sign of hope and progress. An inspiring hypothesis would be whether 'futuricity' (i.e. place evoking positive expectations for future city, combining built environment and nature) could be an important experiential dimension in contradiction with historicity as part of the place attachment. Our study green roof may have represented values not only directly attached to the place itself, but to the *idea* of an innovative future city integrating vegetation with built environment.

454 *4.6 Multisensory aesthetic experience and the urban context*

455

456 Statements reflecting visual aesthetic quality – interest, variety, beauty, and harmony – manifested in the
457 same factor. This result is in line with previous studies that suggested diversity and complexity to be essential
458 elements of visual or aesthetic environmental quality (Tveit et al., 2006; Ode et al., 2008; Hauru et al., 2014;
459 Kirillova et al., 2014).

460 Besides the visual, also audio- and olfactory aspects were frequently mentioned in our data. The
461 sounds, and the scents included neutral or positive perceptions of the cityscape, not necessarily related to any
462 particular source. This means that the city provides a background for the experiences: it is there but it does
463 not 'bother'. Indeed, e.g. soundscape perception consists of various determinants, such as the composition of
464 sound sources, and it is context-specific (Hong and Jeon, 2015). Thus, we argue that it is not necessary to try
465 to completely hide the presence of the city to achieve positive experiences.

466 However, smells and sounds were also evaluated as disturbing, implying immediate planning aspects.
467 Axelsson et al. (2010) reported that technical sounds are more unpleasant than natural sounds, which was
468 also reflected in our study where the respondents mentioned the ventilator as the most disturbing. The strong
469 practical implication for green roof design is that noisy technology on the roofs should be avoided: one
470 misplaced outlet may spoil the experience.

471 Jeon et al. (2011) argued that, visual image, odour, and impressions of openness and density affect
472 soundscape perception. At moderate noise levels (55dBA), high visual quality can improve the pleasantness
473 of the soundscape (Hong and Jeon, 2013, 2015). Furthermore, a review by Dzhambov and Dimitrova (2014)
474 suggests that vegetation may reduce the negative perception of noise, and Hauru et al. (2012) showed that a
475 limited view to the urban matrix may improve the restorative experience. These findings put forth an
476 interesting hypothesis that limiting views from roofs with plantings might have positive impacts on the roof
477 experience where the view to the surroundings does not include natural features, is not picturesque, inspiring,
478 nor loaded with positive meanings.

479 Smell may be the most subjective of the human senses, challenging to measure and define, and thus
480 often characterized simply as good or bad (Agapakis and Tolaas, 2012). Our results are in line with this

finding as the question regarding smells received the least amount of contents from the respondents. Obviously, methodological development is needed to fully assess scents as part of a multisensory experience. Considering the significance of a multisensory experience for the human well-being, it would be interesting to test a green roof deliberately designed for various sensory experiences (cf. e.g. Gonzalez and Kirkevold, 2014 for the benefits of sensory gardens).

We emphasize the wholeness of the perception, interaction of different sensory dimensions, feelings and the specific context of experience on a roof as reflected for example by the liberating multisensory experience, revealed by the free-form answers. A corresponding theme was reported in Mesimäki et al. (2017), where the mental images of urbanites for green roofs described enjoying the height and being close to sky, as well as the feeling of spaciousness and freedom. Also, Ode et al. (2008) regarded visual scale as an important dimension of environmental experience. In the present study cramping and small size were reported by many respondents as disturbing, which poses an interesting challenge for the designer: how to facilitate a positive feeling of space and height, and avoid the feeling of tightness on small roofs, or other small green spaces in a dense city.

4.7 Tempting nature

Visual Interestedness and General Likeability correlated with Tempting Nature, suggesting that these qualities may be connected. This association is further supported by the free-form answers where some form of nature was frequently mentioned as an aesthetically pleasing element on the roof, such as ‘flowers, stones, moss’, and ‘nature, sky’. Furthermore, other responses, e.g. to the question about what things first caught one's attention, combined aesthetic experience explicitly with nature: ’green moss - red sand - grey stones – beautiful’, and ‘verdancy, silence, composition’. Moreover, many respondents smelled, e.g. soil, forest, rain, nature, moss and autumn, heard the hum of the wind, and sensed the fresh wind, indicating multisensority in experiencing nature (cf. Hoyle et al. 2017).

Perhaps the most surprising practical design implication of our study was that that mosses were so readily accepted as part of the roof design, while traditionally, mosses on roofs and lawns have been considered a nuisance.

4.8 Acceptability

In this study the high mean scores of the statements *It is good places like this exist, I like this place,* and *Places like this are compatible with the city* suggest that the studied green roof was accepted as part of the city, and the participants also shared a high positive consensus regarding the place being compatible with the city. Furthermore, General Likability of the roof arose from the results as a factor, indicating that acceptability is essentially different from the other experiential qualities. As e.g. Hauru et al. (2014) suggest, acceptability may be affected by the aesthetic or other experiential qualities perceived on site, but it can also be based on the facts about the place only. Therefore, acceptability, also reflecting the normative attitude towards the place, should not be confused with aesthetic or other experiential qualities provided by the place (cf. Hauru et al., 2014; Hauru, 2015, p. 20, 29, 33).

4.9 Methodological considerations and limitations

There are some considerations regarding surveys including closed and open questions. First, closed questions preceding open ones may lead the respondent to repeat similar ideas. The most interesting findings based on the open questions brought up themes or nuances not revealed by the closed ones, such as the variety of positive feelings and feeling of spaciousness, which might be worth incorporating into the closed questions in future studies.

Second, the low communalities of some of the statements, such as *It is a confusing place* and *This place is modern,* suggest that these statements were difficult to assess (i.e. unclear or unsuited for the site), or represent experiential qualities not implied by other statements or adjectives. The latter suggests a hypothesis that statements and adjectives operationalizing experiences of novelty or innovativeness were not sufficiently

well included in our study, and that new statements reflecting such experiential dimension should be created. This hypothesis is supported by the free-form answers showing that for some respondents the green roof represented a new kind of thinking and hope for the future.

Third, there are methodological issues that imply a need to rethink the design of instruments that use statements or questions to measure human-environment relationships. For example, the current version of PRS measures Coherence only by negative statements that all are formed from the perspective of the 'site' (e.g. ***There is*** *too much going on* rather than ***I feel*** *there is too much going on*). At the same time GenPR gathered all the positive statements and 11 out of the 12 statements on GenPR were phrased so that they contained a personal perception, i.e. 'one-self' (e.g. *Here* ***I feel*** *I can escape the everyday*). These findings are in agreement with the analysis of the full dataset with 45 items: 7 out of 10 negatively phrased statements gathered on one factor (C). Items that reflect the opposites (e.g. *Harmonious*, *It is beautiful here* vs. *It is chaotic here*, *Ugly*) loaded on different factors, suggesting an effect of negative vs. positive items. Had the actual meaning of the items been decisive, the opposites could have loaded on the same factor but with positive vs. negative loadings. Furthermore, the statements that were phrased from the perspective of one-self gathered on different factors from those that referred to the site only: of the nine factors with the highest loading of more than one item, three (B, G, I) contained almost only statements including 'one-self', and six (A, C, D, E, F, H) almost only statements that were phrased to concern the site. We recommend testing for the effect of negative vs. positive phrasing of the statements, and statements that are phrased from the perspective of the observed environment vs. those that emphasize the personal experiences of the respondent, with explicit contrasts specifically designed to test this methodological hypothesis.

The short lecture about green roofs given before the visit, or simply the concept of *green* roof may have produced expectations for a more verdant place than the roof was. The free-form answers revealed negative experiences and observations related to, e.g. unfulfilled expectations concerning the type and lack of vegetation, as well as size and design of the place.

Lastly, as the visitors to the study roof were selected through a registration based on first come first serve rule, the results cannot be straightforwardly generalized to a wider population. Even though the green roof was not the only destination during the event, the participants may have been biased in terms of positive

attitude towards innovative spaces. However, the respondent group represented a variety of professions and educational backgrounds, thus offering relevant data to explore the dimensions of experiencing small green roofs in a dense urban area. Further studies should e.g. test whether similar experiences manifest on different green roofs, in various urban areas, and among different user groups.

Conclusions

Although literature concerning the technical performance of green roofs has dramatically increased during the last 10 years, the experiential quality of green roofs has remained almost terra incognita. While our results offer practical guidelines, they also suggest that investment in research focusing on experiential aspects would be effective in terms of improving the liveability of cities. As people can experience the same space variably, the needs of specific user-groups should be considered. Participatory methods and co-design could be useful for finding and negotiating common ground for high experiential quality. On-site studies in realistic environments are a powerful tool to inform planning and design.

Furthermore, we argue that it is necessary to consciously plan the sensoryscape on a green roof, taking into account the sources of sounds, scents, and the visual stimuli in the immediate surroundings, and further away. We agree with Henshaw (2014) that a ‘new sensory approach to urbanism’ should be developed, and smell and its interactions with other forms of sensory information should be considered in urban design and management.

Finally, following the idea of Campbell at al. (2016) we suggest ecosystem services are constantly re- and co-created via the human interaction with spaces. Therefore, adaptive planning and management require regular data generation to keep researchers and practitioners updated about the experiential ecosystem services that urban green space offers. This is especially important with such emerging nature-based solutions that are not culturally established, and in places with demographic turbulence where meanings and uses may abruptly change.

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Appendices A–D. Supplementary Data

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Fig. 1 The study roof. Photo: Ismo Kirves 2012. The colour version of the photo is displayed in Electronic Appendix A, figure S1.

Table 1 Loadings of PRS statements on two factors representing General Perceived Restorativeness (GenPR) and Coherence. The higher of the two loadings of each statement is in bold. Note that scales of statements 3, 11, 12 and 13 are reversed (=R; see section 2.4 above).

	GenPR	Coherence
1) *My attention is drawn to many interesting things.*	**0.50**	0.31
2) *Being here suits my personality.*	**0.68**	0.29
3) *There is too much going on*. (R)	0.29	**0.68**
4) *I could find many ways to enjoy myself in a place like this.*	**0.65**	0.35
5) *Here I feel able to escape the everyday*.	**0.65**	0.33
6) *I have a sense that I belong here.*	**0.78**	0.18
7) *I have a sense of oneness with this setting.*	**0.72**	0.22
8) *The setting has fascinating qualities.*	**0.75**	0.35
9) *I want to explore the area.*	**0.58**	0.18
10) *I would like to get to know this place better*.	**0.63**	0.21
11) *It is a confusing place*. (R)	0.04	0.21
12) *There is a great deal of distraction.* (R)	0.37	**0.87**
13) *It is chaotic here*. (R)	0.31	**0.74**
14) *I'd like to spend more time looking at the surroundings.*	**0.63**	0.39
15) *Spending time here gives me a good break from my day-to-day routine*.	**0.55**	0.28
16) *I can do things I like here.*	**0.54**	0.18

Table 2 The 11-factor solution of the 29 statements and 17 adjectives, and correlations between the factors A - K. The highest loading of each statement is in bold (note that a statement may have high loadings on several factors). Reversed statements (=R).

	A	B	C	D	E	F	G	H	I	J	K
22) *It is a visually interesting place.*	**0.82**	0.49	0.40	0.63	0.27	0.59	0.48	0.30	0.46	0.37	0.43
23) *There is a lot to observe here.*	**0.67**	0.37	0.19	0.38	0.24	0.43	0.57	0.42	0.37	0.40	0.22
17) *It is beautiful here*.	**0.66**	0.48	0.49	0.60	0.29	0.56	0.42	0.37	0.35	0.50	0.54
Diverse	**0.66**	0.33	0.22	0.32	0.31	0.46	0.35	0.17	0.26	0.34	0.30
Picturesque	**0.65**	0.29	0.40	0.38	0.34	0.45	0.31	0.18	0.33	0.27	0.33
Harmonious	**0.61**	0.36	0.52	0.37	0.41	0.51	0.34	0.31	0.26	0.11	0.26
Well-being	**0.61**	0.34	0.24	0.43	0.36	0.54	0.40	0.46	0.19	0.50	0.37
6) *I have a sense that I belong here.*	0.45	**0.89**	0.20	0.59	0.27	0.51	0.38	0.26	0.44	0.36	0.23
7) *I have a sense of oneness with this setting.*	0.44	**0.77**	0.26	0.40	0.27	0.48	0.37	0.17	0.40	0.24	0.33
5) *Here I feel I can escape the everyday.*	0.27	**0.64**	0.35	0.40	0.14	0.44	0.31	0.09	0.46	0.39	0.48
16) *I can do things I like here.*	0.37	**0.60**	0.16	0.40	0.15	0.32	0.24	0.35	0.20	0.37	0.33
21) *I feel I understand this place.*	0.55	**0.59**	0.23	0.39	0.21	0.39	0.38	0.29	0.29	0.27	0.29
12) *There is a great deal of distraction.* (R)	0.38	0.21	**0.85**	0.32	0.22	0.35	0.23	0.29	0.41	0.21	0.20
13) *It is chaotic here.* (R)	0.37	0.23	**0.76**	0.36	0.06	0.24	0.17	0.39	0.13	0.19	0.22
3) *There is too much going on.* (R)	0.16	0.23	**0.69**	0.17	0.25	0.25	0.06	0.10	0.26	0.12	0.30
Restless (R)	0.38	0.19	**0.69**	0.25	0.36	0.30	0.11	0.51	0.14	0.13	0.08
Ugly (R)	0.42	0.25	**0.52**	0.44	0.13	0.46	0.22	0.28	0.28	0.35	0.42
Confined (R)	0.30	0.24	**0.42**	0.32	0.39	0.22	0.10	0.35	0.23	0.12	0.09
Everyday (R)	-	0.09	**-0.50**	-0.18	-0.03	-0.28	-0.29	-0.17	-0.31	-0.22	-0.17
27) *It is good that places like this exist*.	0.40	0.50	0.32	**0.92**	0.27	0.45	0.26	0.36	0.47	0.47	0.34
29) *Places like this fit in into the city*.	0.34	0.36	0.23	**0.74**	0.20	0.41	0.27	0.37	0.41	0.37	0.30
28) *I like this place*.	0.41	0.50	0.39	**0.68**	0.34	0.56	0.33	0.38	0.41	0.43	0.33
Boring (R)	0.58	0.37	0.53	**0.66**	0.24	0.56	0.40	0.43	0.47	0.58	0.42
Nice	0.47	0.41	0.30	**0.58**	0.20	0.57	0.30	0.44	0.46	0.56	0.30
26) *This place is modern.*	0.33	0.28	0.11	**0.48**	0.12	0.24	0.27	0.16	0.18	0.18	0.14
19) *The air is fresh here*.	0.32	0.17	0.22	0.27	**0.83**	0.29	0.17	0.21	0.16	0.23	0.23
Fresh	0.44	0.26	0.22	0.48	**0.65**	0.56	0.33	0.42	0.29	0.39	0.20
18) *The soundscape is pleasant here.*	0.28	0.25	0.31	0.17	**0.61**	0.41	0.20	0.13	0.28	0.18	0.24
20) *This is a mysterious place*.	0.32	0.26	0.12	0.28	**0.44**	**0.44**	0.23	-0.07	0.25	0.40	**0.44**
Lively	0.53	0.38	0.28	0.48	0.32	**0.77**	0.36	0.55	0.38	0.40	0.25
24) *I can sense nature in this place*.	0.52	0.51	0.35	0.44	0.34	**0.75**	0.32	0.17	0.44	0.29	0.40
Verdant	0.46	0.30	0.22	0.40	0.37	**0.69**	0.29	0.55	0.25	0.34	0.18
Tempting	0.57	0.49	0.36	0.58	0.47	**0.60**	0.42	0.45	0.52	0.59	0.52
25) *This looks like a place where many insects and invertebrates live*.	0.30	0.32	0.24	0.27	0.19	**0.49**	0.24	0.12	0.15	0.25	0.23
9) *I want to explore the area*.	0.55	0.38	0.18	0.36	0.20	0.36	**0.86**	0.27	0.38	0.19	0.12
10) *I would like to get to know this place better*.	0.43	0.38	0.24	0.42	0.24	0.47	**0.86**	0.33	0.32	0.54	0.44
8) *The setting has fascinating qualities*.	0.55	0.52	0.36	0.52	0.36	0.59	**0.62**	0.37	0.52	0.55	0.46

14) *I'd like to spend more time looking at the surroundings*.	0.53	0.41	0.36	0.36	0.24	0.44	**0.56**	0.31	0.47	0.42	0.45
Safe	0.31	0.25	0.25	0.39	0.22	0.35	0.21	**0.63**	0.21	0.22	0.26
Scary (R)	0.16	0.07	0.29	0.18	0.10	0.18	0.15	**0.60**	0.11	0.13	-0.05
11) *It is a confusing place*. (R)	0.05	0.12	0.18	0.07	-0.18	-0.02	-0.07	**0.28**	0.10	-0.05	-0.20
4) *I could find many ways to enjoy myself in a place like this*.	0.24	0.56	0.28	0.54	0.15	0.44	0.26	0.25	**0.76**	0.50	0.41
1) *My attention is drawn to many interesting things*.	0.48	0.26	0.32	0.37	0.24	0.34	0.39	0.16	**0.64**	0.24	0.28
2) *Being here suits my personality*.	0.43	0.62	0.28	0.59	0.39	0.54	0.34	0.42	**0.63**	0.33	0.19
Exciting	0.51	0.32	0.23	0.41	0.32	0.45	0.43	0.22	0.34	**0.68**	0.33
15) *Spending time here gives me a good break from my day-to-day routine*.	0.37	0.49	0.29	0.36	0.25	0.36	0.25	0.15	0.37	0.25	**0.62**

	A	B	C	D	E	F	G	H	I	J	K
B	0.47										
C	0.42	0.26									
D	0.53	0.54	0.38								
E	0.40	0.28	0.23	0.30							
F	0.58	0.48	0.41	0.57	0.44						
G	0.53	0.34	0.22	0.36	0.23	0.44					
H	0.43	0.30	0.32	0.47	0.25	0.37	0.27				
I	0.35	0.45	0.36	0.49	0.25	0.51	0.39	0.22			
J	0.31	0.31	0.24	0.53	0.21	0.54	0.39	0.34	0.38		
K	0.32	0.30	0.34	0.39	0.19	0.48	0.32	0.07	0.30	**0.61**	

Appendix A. The study roof

Fig. S1 The study roof. Photo: Ismo Kirves 2012.

Fig. S2 Vegetated areas and paved paths on the study roof. Moss-sedum vegetation in the front, and newly constructed experimental plots (separated with gravel) in the middle. Photo: Malgorzata Gabrych 2012.

Figs. S3–S4 Surrounding roof scenery (opposite to Figs S1 and S5–S6), and patio with two chairs, a table and flower pots. In Fig S4, the crane of the construction site nearby is visible.

Fig. S3 Photo: Taina Suonio 2012.

Fig. S4 Photo: Malgorzata Gabrych 2012.

Figs. S5–S6 Surrounding wall scenery (opposite to Figs. S3–S4): the library building with a balcony (S5), and colorful curtains (S6).

Fig. S5 Photo: Malgorzata Gabrych 2012.

Fig. S6 Photo: Taina Suonio 2012.

Appendix B. Age, living environment, and expertise of the respondents

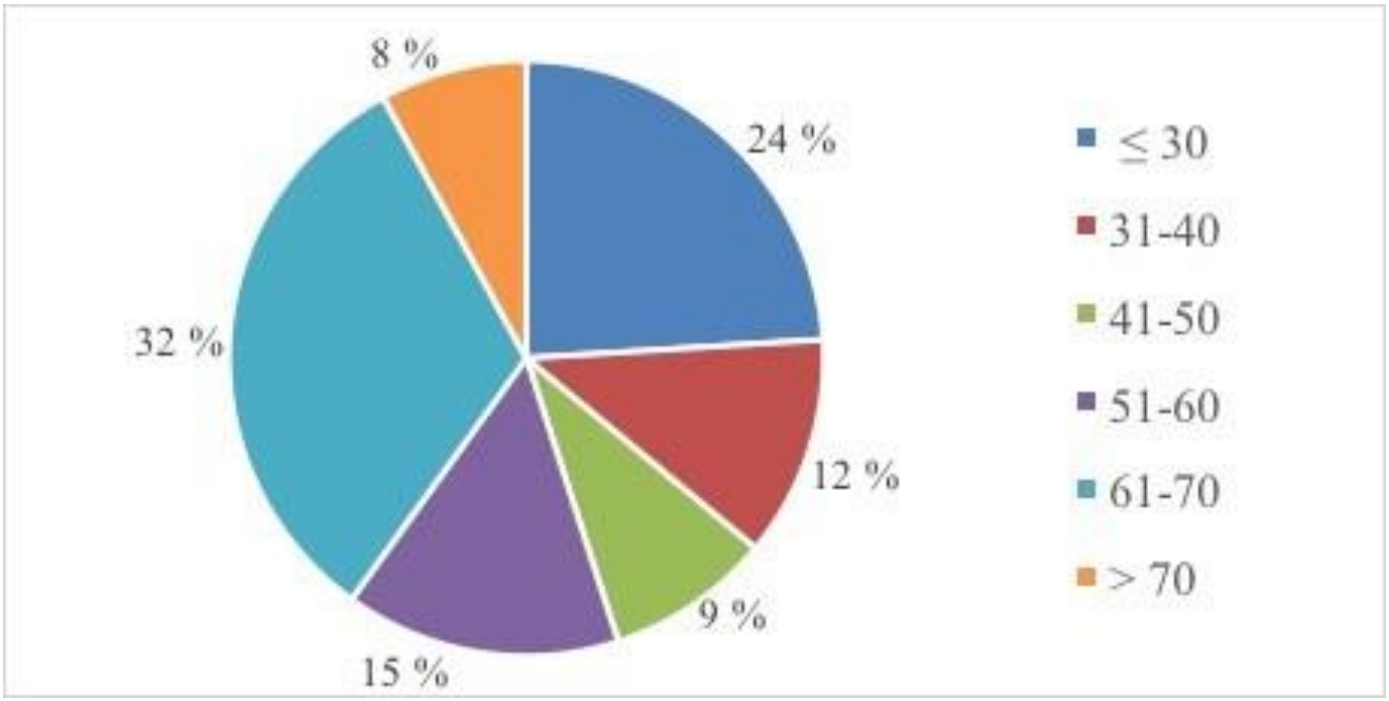

Fig. S7 Age of the respondents. Age groups as percentages of the 165 respondents who answered this question.

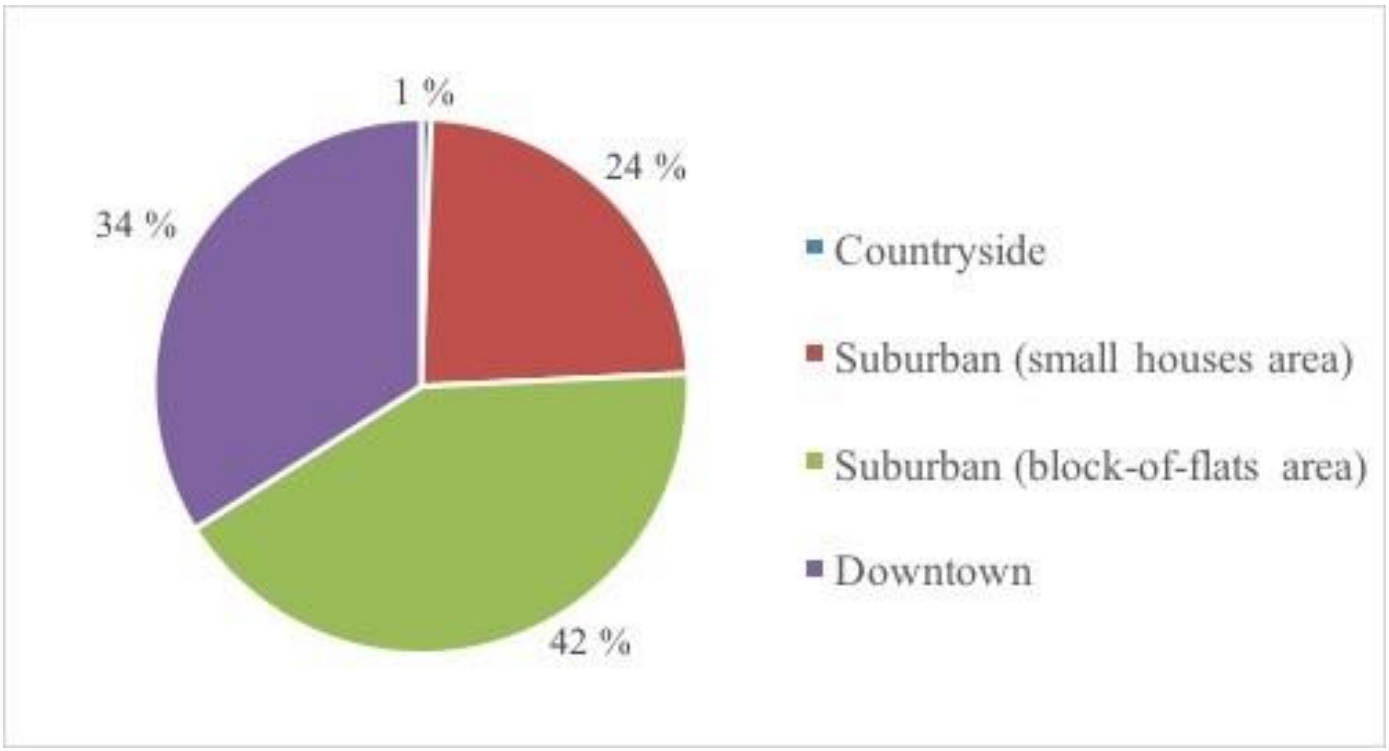

Fig. S8 Living environment of the respondents. Living environment groups as percentages of the 165 respondents who answered this question.

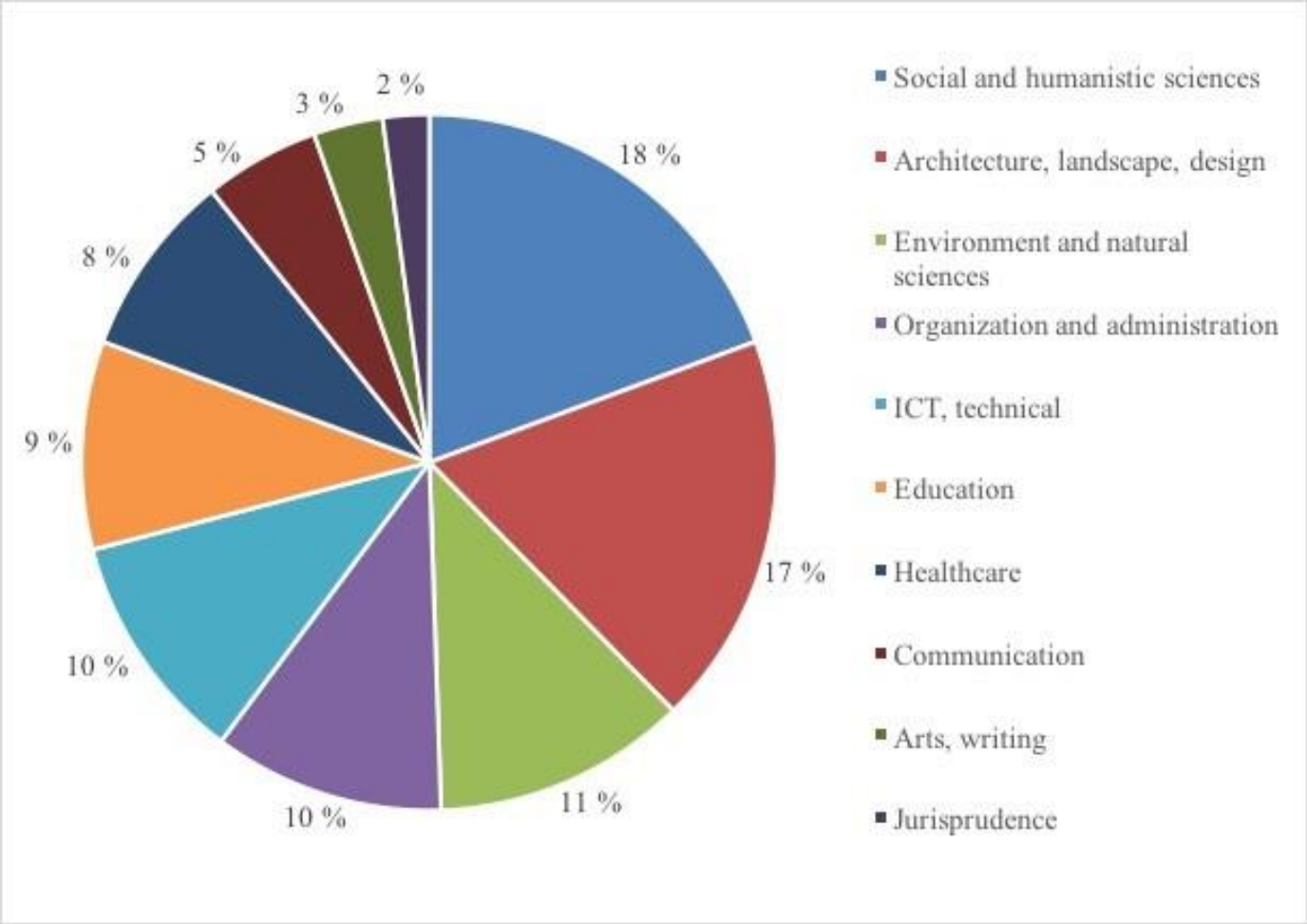

Fig. S9 Expertise of the respondents. We categorized the expertise mentioned by 140 respondents (originally 160 responses to this question, out of which 20 were so unclear that they could not be categorized). However, some respondents reported to be experts in many fields, thus the total number of mentioned expertise was 174.

Appendix C. The Questionnaire

Respondents were given the following introduction:

There is a green roof landscape around you. We are interested in your experience right at the place where you are standing. To help us understand your experience, we have provided the following statements for you to respond to. First, look around you, and then, carefully read each statement. Ask yourself *"How much does this statement apply to my experience right here?"*

After having answered to the close-ended questions, and, standing at the same place, please answer with a couple of words to the open-ended questions at the end of the questionnaire.

Note that there are no right or wrong answers to the questions.
We are interested in your personal experience here and now.

Please circle for each statement the alternative that applies best to your own experience here and now.

1= not at all, 2 = Very little, 3 = Fairly little, 4 = Neither little nor much, 5= Fairly much, 6 = Very much, 7 = Completely.

1) My attention is drawn to many interesting things.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
2) Being here suits my personality.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
3) There is too much going on.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
4) I could find many ways to enjoy myself in a place like this.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
5) Here I feel I can escape the everyday.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
6) I have a sense that I belong here.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
7) I have a sense of oneness with this setting.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
8) The setting has fascinating qualities.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
9) I want to explore the area.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
10) I would like to get to know this place better.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
11) It is a confusing place.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
12) There is a great deal of distraction	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
13) It is chaotic here.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
14) I'd like to spend more time looking at the surroundings.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
15) Spending time here gives me a good break from my day-to-day routine.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
16) I can do things I like here.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
17) It is beautiful here	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
18) The soundscape is pleasant here.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
19) The air is fresh here.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
20) This is a mysterious place.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
21) I feel I understand this place.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
22) It is a visually interesting place.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
23) There is a lot to observe here.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
24) I can sense nature in this place.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
25) This looks like a place where many insects and invertebrates live.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7

26) This place is modern.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
27) It is good that places like this exist.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
28) I like this place.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
29) Places like this fit in into the city.	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7

Please evaluate, how well the following adjectives describe this environment. Please circle for each adjective the alternative that applies best to your own experience.

1= not at all, 2 = Very little, 3 = Fairly little, 4 = Neither little nor much, 5= Fairly much, 6 = Very much, 7 = Completely.

I think that the landscape is:

Ugly	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
Nice	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
Harmonious	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
Restless	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
Diverse	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
Everyday	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
Piqturesque	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
Well-being	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
Exciting	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
Boring	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
Lively	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
Verdant	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
Fresh	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
Confined	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
Tempting	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
Scary	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7
Safe	1-- 2 -- 3 -- 4 -- 5 -- 6 -- 7

Observe this environment with all your senses and answer following questions considering what you are experiencing right now in this place.

1) What things first caught your attention?
2) If there are some aesthetically pleasing things in the place, what are they?
3) If there are some disturbing things in the place, what are they?
4) What sounds do you hear?
5) What do you smell?
6) What kinds of feelings does the place evoke in you?

Appendix D. Classified contents of free-form answers.

1. What things first caught your attention?

Main category	Examples of mentioned things, *word to word quotations* (translated from Finnish) from the original answers are shown in italics
Elements within the roof	Objects on the roof, e.g. concrete slabs, red substrate, terrace chairs, different surfaces
Mosses	Mosses, moss cover, *lovely green moss*
Design of the roof	Composition of different features, space, forms, shapes, *harmonic layout of surfaces, great use of small space*
Colors, verdancy	Different colors, green, greenness, verdant, *intensive color of green moss, great colors and contrasts*
Characterizations of the place and space	Beautiful, small, cozy, high, spaciousness, *just as stepping in the middle of a forest, green area in the middle of stony city, new constructional idea*
Built environment around the roof	Roof landscape, roofs, walls and buildings in the surroundings, *fine roofs around*
Plants and mushrooms	Plant species, plant communities, plant surfaces
Environmental attributes	(Respiratory) air, light/sunshine, wind, smells, sounds, scents, *fresh wind, sounds of the city*
Flowers	Flowers, flower pots, *yellow daisies*
Negative things	Less plants/not as fancy as expected, (unexpectedly) small, unfinished, *too many concrete and ugly slabs, buzzing sound of the air conditioning*
Sky, horizon	

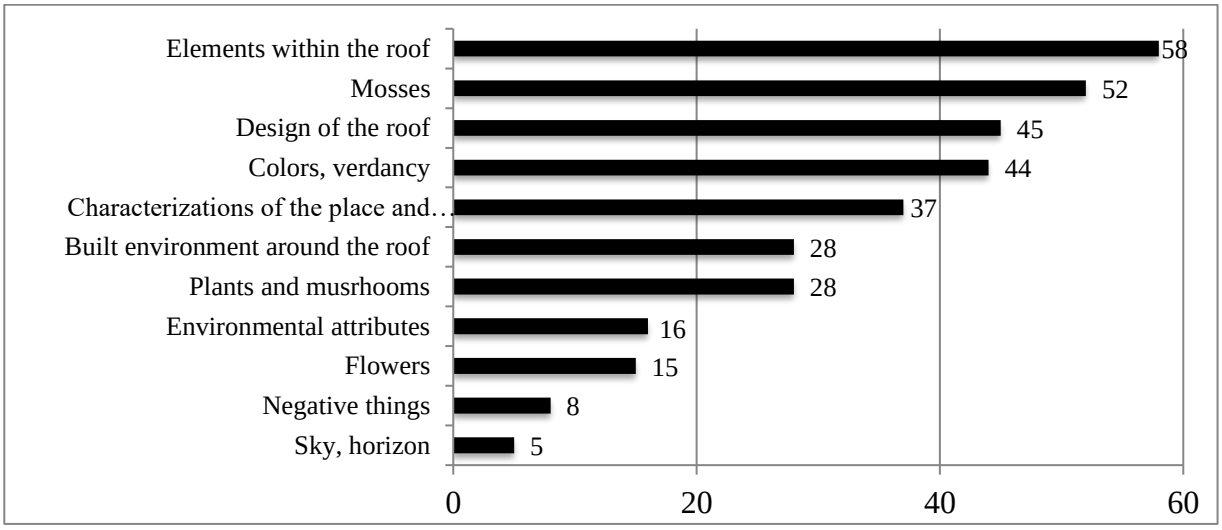

Fig. S10 Classified answers to the question: 'What things first caught your attention?' Altogether 165 respondents (93% of all respondents, N=178) answered to this question. The x-axis and the numbers beside each bar show the number of mentions in each category.

2. If there are some aesthetically pleasing things in the place, what are they?

Main category	Examples of mentioned things, *quotations*
Colors, verdancy	Green, different shades of green, colors of the buildings, greenness, richness of colors, *beautiful colors, intensive green color*
Elements within the roof	Furniture, (natural) rocks, macadam paths, substrate, slabs, tiles
Design of the roof	Composition of different sectors, elements and materials on the roof and their interaction, shapes, forms, scale, diversity/versatility (of e.g. elements, shapes), balance, *harmonic unity, beautiful shapes, modernly symmetric, nicely arranged plants and paths, combination of mosses, plants and stones.*
Mosses	Mosses, moss cover, *velvety moss, moss is rather natural*
Built environment around the roof	(Roof) landscape, different types of roofs, forms and shapes of the roofs, old buildings, facades, windows, *urban milieu, beautiful views, I liked the walls of the buildings – do they store warmth for the plants?*
Flowers	Wild flowers, flowerpots, flower arrangements
Characterizations of the space	Spaciousness, openness, beautiful/beauty, small, intimacy, simplicity, cleanliness, closeness to nature, surprising, connection to urban environment, *small and neat garden, barrenness is attractive, a lot of space above*
Vegetation, nature	Plants, high/short plants, stonecrops (Sedum), mushrooms, funnel chantarelles, *varying vegetation of the roof*
Sky, horizon	Blue sky and clouds, sky is close, open sky, *great bright sky*
Environmental attributes	Good weather, air, sun, light, *slant evening light*

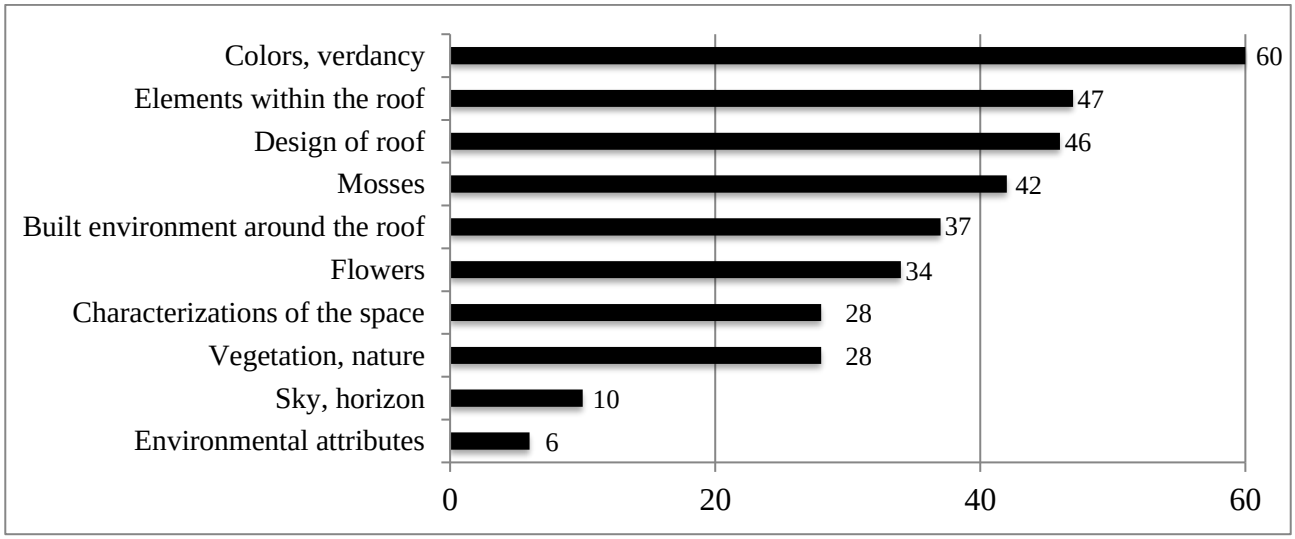

Fig. S11 Classified answers to the question: 'If there are some aesthetically pleasing things in the place, what are they?' Altogether 162 (91%) respondents answered to this question. The x-axis and the numbers beside each bar show the number of mentions in each category.

3. If there are some disturbing things in the place, what are they?

Main category	Examples of mentioned things, *quotations*
Noise	Air conditioner/ventilator, drone, hum, whirr, creak, wheezy sound, construction noise, traffic noise from the street
Built environment around the roof	Walls, (garish, bright) colors, balcony (and people on it), construction site, crane, restricted view
Built elements on the roof	Concrete slabs, fences, *flowerpots do not fit here*
Characterizations of the space	Small, tightness, restless, too close to buildings, too stony, dull, lack of action
Design of the roof	too many/composition of slabs, flat/planar vegetation, messy, formality, too ordered, *perhaps a little bit too much of everything, not quite harmonious*
Lack or unsuitable choices of vegetation	Lack of green, stunted vegetation, lack of high vegetation and climbing plants, *I miss a sheltered corner for spending time, mosses remind me of harms related to humidity and moisture*
Environmental attributes	Wind, windy
Nothing	
Smells	Smells from the canteen, construction site

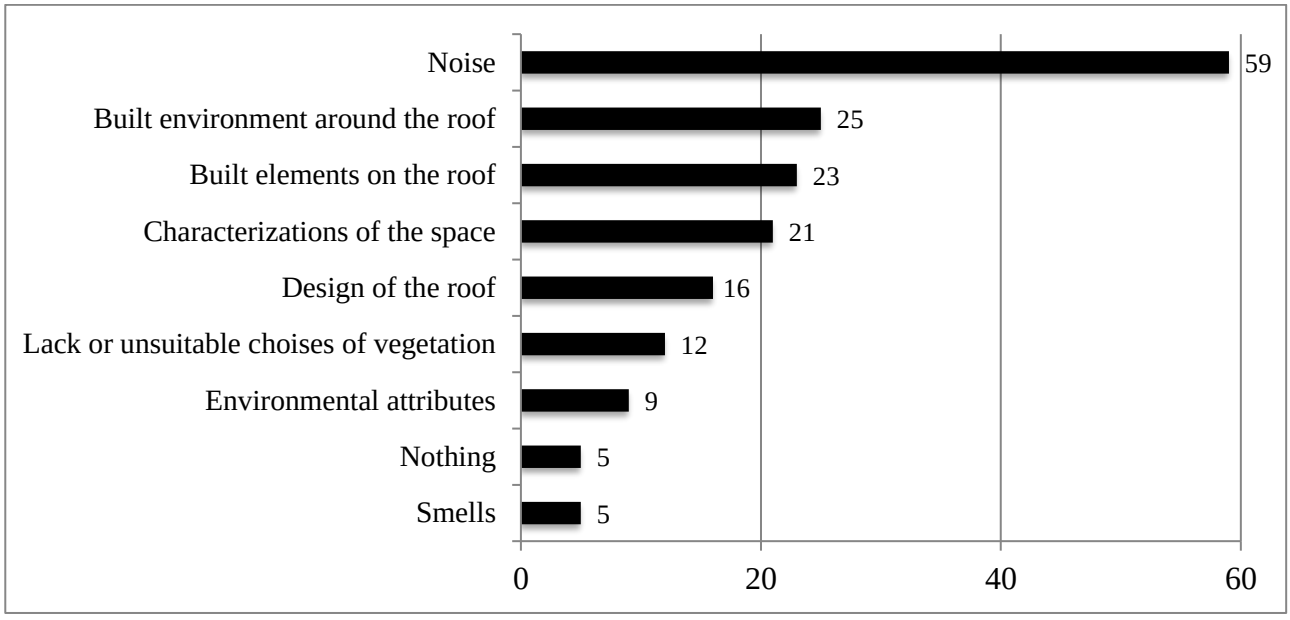

Fig. S12 Classified answers to the question: 'If there are some disturbing things in the place, what are they?' Altogether 129 (72%) respondents answered to this question. The x-axis and the numbers beside each bar show the number of mentions in each category.

4. What sounds do you hear?

Main category	Examples of mentioned things, *quotations*
Air conditioning	All kinds of buzz, whirr, drone, burr, squeak, whine etc. characterizations were interpreted as sounds of air conditioning
Traffic	Cars, trams, honking, aeroplane, *traffic noise is surprisingly mild, faint traffic noise*
Construction site	Including sounds from 'machines' (cranes etc.)
Human sounds	Speech, walking, coughing, rustling of questionnaire papers
Sounds of the city	City sounds in general/background sound of the city, *hum of the city, occasional sounds from the street*
Sounds of nature	Wind, sound of gravel, birds, seagulls
Nothing	

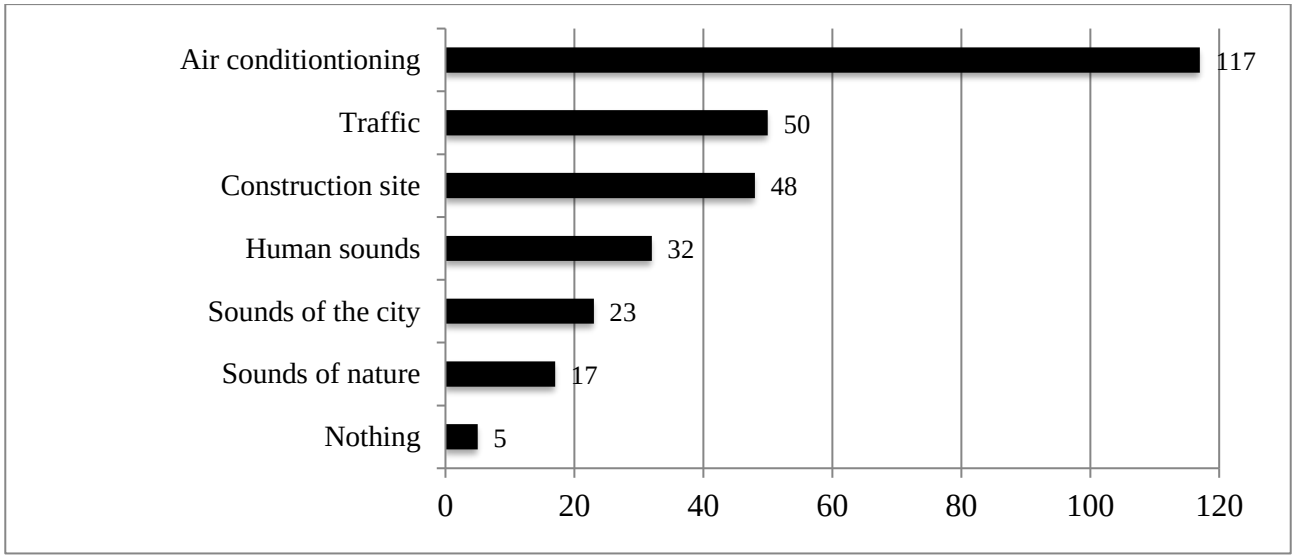

Fig S13 Classified answers to the question: 'What sounds do you hear?' Altogether 167 (94%) respondents answered to this question. The x-axis and the numbers beside each bar show the number of mentions in each category.

5. What do you smell?

Main category	Examples of mentioned things, *quotations*
Fresh air	Fresh air, wind, sea air
Nothing	Nothing, almost nothing
Food	Smell from the canteen (likely emanating from somewhere in the building through the air conditioning)
Nature, seasons	Forest, vegetation, tussock, moss, soil, rain, moist, autumn, cold, *moist wind, crisp autumn*
City	Smells of the city (in general), exhaust gas, dust of the city, asphalt, construction site
Other	sharp, nice, soft, sweet, sun, smoke, stuffy

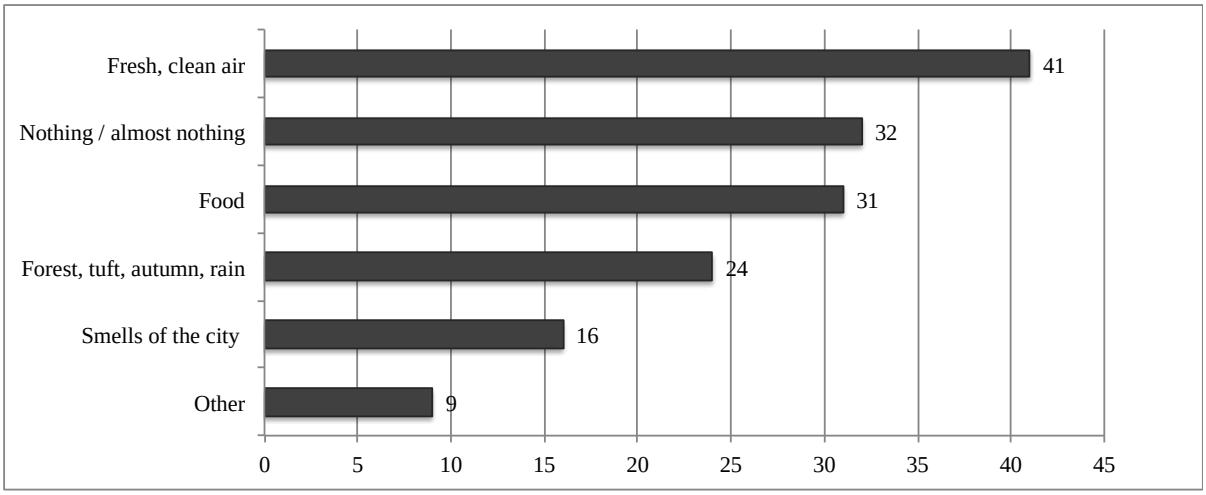

Fig S14 Classified answers to the question: 'What do you smell?' Altogether 157 (88%) respondents answered to this question. The x-axis and the numbers beside each bar show the number of mentions in each category.

6. What kinds of feelings does the place evoke in you?

Main category	Examples of mentioned things, *quotations*
Pleasant	Pleasant, joy, love, cozy, sympathy, nice, good feeling/mood, smile, admiration, wonderful, fascinating, *oasis of the city center, it is a great feeling to be here, sunny feelings, nice place to visit*
Peaceful, relaxed	Peaceful, calm, calming atmosphere, relaxed, unhurried, leisurely, serene, escape (from everyday life), *calming greenness, positive peace, a place to rest for a while, inspiring tranquility*
Interested, inspiring	Curiosity, excitement, surprising, hope (for the future), inspiring, *this is future, something new!, great idea, more places like this*
Desire to stay, to come back	Stay longer, lie in a hammock, relax with a book, have lunch, sit down, look at the sky, meditate, grow useful plants, follow plants over time, see bugs, play, hide, *I could come here to calm down, I would like to stroke the moss*
Negative	Boring, disappointment, tight, *could be higher up, I waited for more*
Freedom	Liberating, freedom to breath, spacious, *own space in the middle of urban landscape*
Familiar, nostalgic	Coziness, memories from childhood or past, *sedums and mosses remind of the cottage island of the family, climbing in nature in childhood, old memories from the 60's*
Confused, vague	Ambivalent, questions
Feelings related to the environmental attributes	Fresh (ref. to air), autumnal
Feelings related to identity	*European mixed to Finnish identity, this is a true Helsinkian place, A cheap trip to Amsterdam!*
Nothing	*Nothing at this kind of group visit*
Other	Aesthetic pleasure, refreshing, harmonious/harmony, connection

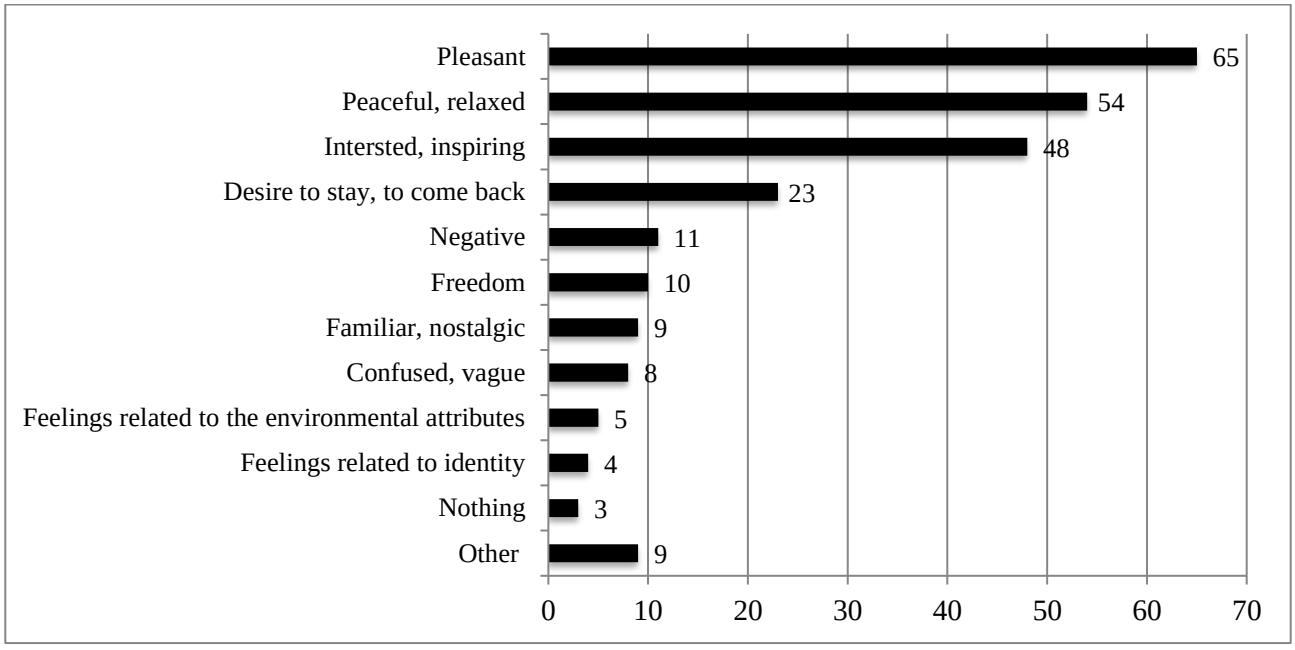

Fig. S15 Classified answers to the question: 'What kinds of feelings does the place evoke in you?' Altogether 162 respondents (91%) answered to this question. The x-axis and the numbers beside each bar show the number of mentions in each category.